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The Reliability of the Seated Medicine Ball Throw for Distance

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Abstract Measuring distance thrown during the Seated Medicine Ball Throw (SMBT) has been used frequently within the literature to quantify upper body explosiveness, due to the test being easy to learn, low-risk, and requiring minimal equipment. The reliability of distance thrown in the SMBT has not been broadly reported, nor have familiarization protocols been thoroughly documented. The purpose of this study is to assess the reliability of distance thrown during the SMBT as a representative measurement for upper body explosiveness in active, recreationally trained adults. Before testing, 20 subjects completed a dynamic warm-up. After learning proper technique, subjects were familiarized with the exercise by completing continuous trials using a 10 lb medicine ball, with 1 minute of rest between trials, until three consecutive throws within 0.25 m were achieved. Subjects rested 20 minutes, repeated the warm-up, and then completed 6 trials of the SMBT where distance of each throw was measured. Any trial in which technique deviated significantly from the instructions was repeated. Intraclass correlation coefficients (ICCs) were used to assess reliability between trials. Distances thrown for trials 1-6 were as follows: 3.43±0.99 m, 3.41±0.95 m, 3.48±1.00 m, 3.48±1.00 m, 3.46±1.03 m, and 3.54±1.05 m respectively. ICCs for consecutive trial pairs ranged from 0.97-0.99. These findings suggest that distance thrown is a reliable representative measure of upper body explosiveness in recreationally trained adults. The familiarization protocol used was sufficient for producing consistent performance.

Keywords: *medicine ball, upper-body explosiveness, field testing, impulsive ability*

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1. Introduction

Upper body explosiveness is an essential ability for a wide variety of populations and contributes greatly to activities of daily living that involve reaching, pushing, pulling, lifting, and stabilization [1]. A decline in upper body explosiveness is associated with an increased risk in all-cause mortality [2,3]. It is important to be able to reliably quantify upper body explosiveness in order to evaluate individuals against normative data and assess change over time in healthy, aging, and injured populations [1], as well as athletic populations [4].

The Seated Medicine Ball Throw (SMBT) has been used frequently within the literature to quantify upper body explosiveness, due to its feasibility in the practical setting. The SMBT is a relatively simple and easy-to-master movement [1,5] that can be applied to many different populations including children [6], athletes [4,7], healthy adults [8,9], and older adults [1]. The SMBT only requires a measuring tape, chair, and a medicine ball. The measuring tape is laid at the base of the apparatus and distance of the where the thrown medicine ball lands is recorded. While performance in the SMBT and its variations can be measured in other ways, such as motion capture [8,10,11], force plates plus motion capture [12] and with a medicine ball with an embedded accelerometer [5,8,11], these methods are typically more costly and require greater technical expertise.

The reliability of a given test is an important consideration for the test’s usefulness to practitioners. Reliability refers to the notion of consistency, wherein repeated measurements of a phenomenon under similar conditions using a reliable test will yield results that are nearly identical to one another [13]. Test-retest reliability is a specific subset of reliability in which the absolute and relative reliability is assessed for multiple measurements of the same subjects, made using the same measuring device, and with subjects tested under identical conditions [14]. Use of the same subjects and conditions allows estimation of the magnitude of error attributable to the measurement tool itself, as factors such as fatigue, practice, subject variability, time between testing, and environmental conditions can all influence results [13]. While estimation of the test-retest reliability of a given tool does not ensure accuracy or validity, it is a critical step.

The reliability of the SMBT distance thrown has been reported in several studies with male college students [15], regionally competitive athletes [16], and older adults [1]. Gillespie and Keenum [15] only used ICCs to determine reliability, and didn't include females within the sample. Inclusion of the ICC only is problematic, because while the ICC statistic provides insight into the magnitude of agreement and/or consistency of tests [17], it shows no information about the magnitude of the error in relative or absolute terms, nor does it detect changes in the mean [18]. Therefore, the purpose of this study is to evaluate the within-session test-retest reliability of the measured distance thrown (m) during the SMBT was assessed in a healthy adult sample of men and women.

2. Methods

2.1. Participants

Twenty healthy undergraduate students volunteered for this study (8 females, 12 males, height: 170.2 ± 10.5 cm, mass: 73.2 ± 16.0 kg, age: 23.8 ± 3.3 y). Inclusion criteria were that participants had no upper body injury within the last 6 weeks, were participating in structured exercise at least once per week, and had performed no strenuous upper body exercise in the 48 hours prior to testing. Subjects gave written informed consent after being briefed verbally on study procedures. This study was approved by the University Committee for the Protection of Human Subjects.

2.2. Procedures

This protocol has been reported previously [5]. Briefly, to perform the SMBT, the subjects held the 10 lb medicine ball (Ballistic Ball; Assess2Perform, Montrose, Colorado, USA) against their chest until they heard an audible cue to begin the throw, at which point they threw the ball as far as possible in front of them. The subjects were instructed to keep their upper back pressed against the bench, staying in contact throughout the full throw using maximal effort. Instructions on angle of the throw were provided both in warm ups and in familiarization (approximately 40-45°). This angle was not measured beyond visual observation, nor restricted with obstacles or targets, based on previous research which found that an unrestricted launch angle resulted in greater throw distances with the two-hand seated shot put throw (nearly identical to the SMBT) [15]. Horizontal distance of the thrown medicine ball was measured from the base of the bench (the "zero" mark of the tape measured was aligned with the front edge of the seat) to the rearmost point of contact of the medicine ball on the first impact, with a resolution of 5 cm.

Prior to testing, subjects executed a dynamic warm-up protocol consisting of callisthenic and body weight exercises for the upper and lower body, followed by 5 SMBT warm up trials. Subjects then rested for 2 minutes before beginning the familiarization phase of the study. Participants performed repeated familiarization trials with 1 minute rest periods between trials, until their performance stabilized and was no longer improving, deemed by three consecutive trials that were within 0.25 m of each other [5]. Previous research with the backwards overhead medicine ball throw used a similar protocol to achieve familiarization with three trials within 0.5m as the criteria; this was halved for the present study due to distances thrown in the SMBT being approximately half of those observed in the previous study [4].

After becoming familiar with the exercise, subjects were given a 20 minute rest period before repeating the dynamic warm up. After completing the warm-up, subjects performed 6 trial throws using the same technique; invalid tests were repeated so that a total of 6 correctly done trials were collected. A trial was deemed valid if: 1) the subject's upper back remaining in contact with the bench at all times during the throw 2) the subject clearly gave and felt as though they had given maximum effort.

Figure 1. Seated Medicine Ball Throw (SMBT) test

2.3. Statistical Analysis

The current study examined the test-retest reliability of the measured distance of the thrown MB (m) from a maximal SMBT attempt. Six trials of the SMBT were conducted. There is currently little consensus as to the optimal methods for determining the reliability of a test [17-23]. Multiple approaches were used in order to comprehensively examine both absolute and relative reliability. Interclass (Pearson's r) and intraclass reliability coefficients (ICC: type 3,1), the mean difference between trials, and the standard error of measurement (SEm) were calculated for consecutive trials, including 90% upper and lower limits (UL, LL). Bland-Altman plots were also constructed in order to examine error uniformity [20]. Typical error expressed as a CV% was also calculated using the log-transformed trial data. A spreadsheet by Hopkins [18] and Microsoft Excel 2013 was used for all statistical calculations. Distance data were peer reviewed for accuracy prior to analysis [24]. This approach is consistent with numerous reliability investigations [5,25,26,27,28]. In order to determine the magnitude of change in performance that must be exceeded to be sure that a "true" change occurred, the smallest detectable difference (SDD) was calculated using equation 1 [19,22].

$$SDD = 1.95 \times \sqrt{2} \times SEM. \quad (1)$$

3. Results

The participants (n=20) completed all of the SMBT (6 trials) without complication. Participant demographics are provided in Table 1. Table 2 provides the SMBT distances across the 6 trials (meters).

Hopkins [18] suggests log-transforming repeated trial data for the purpose of quantifying typical error. The trial data in the current study suggested uniform error. The typical error (or coefficient of variation percent) ranged from CV%=3.2-4.7 percent.

Table 1. Demographics (mean±sd)

N	Age (years)	Height (cm)	Mass (kg)
Combined n=20	23.8±3.3	170.2±10.5	73.2±16.0
Female n=8	22.5±2.9	160.8±7.1	63.6±8.9
Male n=12	24.7±3.4	176.5±7.2	79.7±16.7

Table 2. Seated Medicine Ball Throw Distance Trial Scores

Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
3.43±0.99	3.41 ±0.95	3.48±1.00	3.48±1.00	3.46±1.03	3.54±1.05

Data represented as mean±sd, distance: meters.

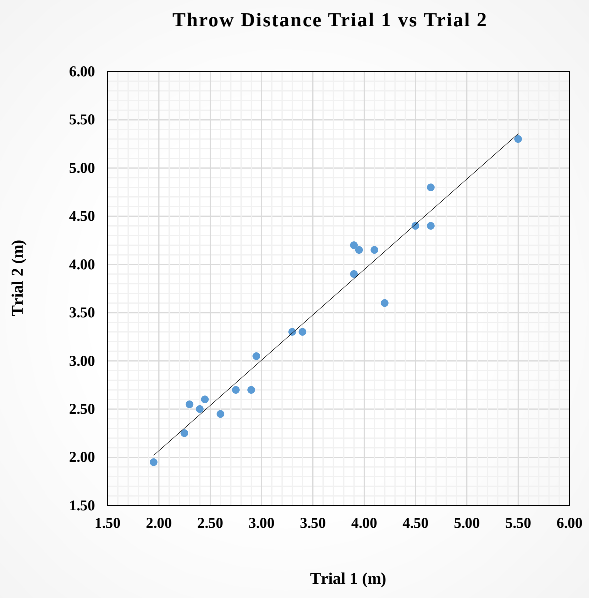

Figure 2. Scatter Plot Distance Trial 1 and 2 Scores

The scatter plot comparing trial 1 and 2 scores (Figure 2) exhibits a strong linear relationship. The Bland-Altman plot of trial 1 and 2 scores (Figure 3) exhibited-uniform error. Only one trial pair (5%) exceeded the limits of agreement suggesting adequate repeatability [20]. Graphs and plots for the sequential trial pairs were similar to Figure 2 and Figure 3 and as such, are not included in the manuscript.

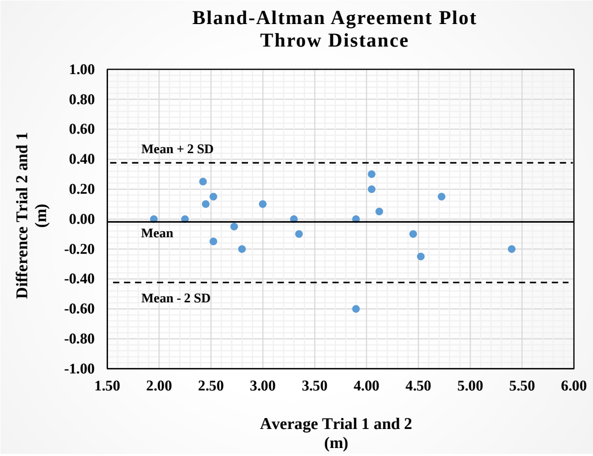

Figure 3. Bland-Altman plot comparing the trial average scores versus the difference scores (Trial 1 and 2)

Table 3 - Table 7 provide the reliability assessments for the sequential trial scores. The mean difference between trial scores ranged from -0.02 to 0.08 m. The interclass reliability coefficients ranged from r=0.97 to 0.99. The intraclass reliability coefficients ranged from ICC=0.97 to 0.99. The standard error of measure for the sequential trials ranged from SEm=0.12 to 0.16 (m). The SEm across all 6 trials was SEm=0.14 (m). The SDD was 0.39 m.

Table 3. Seated Medicine Ball Throw Distance Trial 1 and 2 Statistics

Statistic		Upper Limit	Lower Limit
Δ Means (m)	-0.02±0.21	0.06	-0.10
r	0.98	0.99	0.96
ICC	0.98	0.99	0.86
Typical Error (CV%)*	4.2	5.8	3.3
SE_m	0.15	0.20	0.12

90% Confidence UL-upper limit, LL-lower limit. *Typical error expressed as a CV% based on Log-transformed data. SEm- standard error of the measure. r- Pearson correlation coefficient. ICC- Intraclass correlation coefficient. m- meters.

Table 4. Seated Medicine Ball Throw Distance Trial 2 and 3 Statistics

Statistic		Upper Limit	Lower Limit
Δ Means (m)	0.07±0.23	0.16	-0.02
r	0.97	0.99	0.94
ICC	0.97	0.99	0.95
Typical Error (CV%)*	4.7	6.5	3.7
SE_m	0.16	0.23	0.13

90% Confidence UL-upper limit, LL-lower limit. *Typical error expressed as a CV% based on Log-transformed data. SEm- standard error of the measure. r- Pearson correlation coefficient. ICC- Intraclass correlation coefficient. m- meters.

Table 5. Seated Medicine Ball Throw Distance Trial 3 and 4 Statistics

Statistic		Upper Limit	Lower Limit
Δ Means (m)	0.00±0.17	0.07	-0.06
r	0.99	0.99	0.97
ICC	0.99	0.99	0.97
Typical Error (CV%)*	3.3	4.5	2.6
SE_m	0.12	0.16	0.09

90% Confidence UL-upper limit, LL-lower limit. *Typical error expressed as a CV% based on Log-transformed data. SEm- standard error of the measure. r- Pearson correlation coefficient. ICC- Intraclass correlation coefficient. m- meters

Table 6. Seated Medicine Ball Throw Distance Trial 4 and 5 Statistics

Statistic		Upper Limit	Lower Limit
Δ Means (m)	-0.02±0.17	0.04	-0.09
r	0.99	0.99	0.97
ICC	0.99	0.99	0.97
Typical Error (CV%)*	3.2	4.4	2.5
SE_m	0.12	0.16	0.09

90% Confidence UL-upper limit, LL-lower limit. *Typical error expressed as a CV% based on Log-transformed data. SEm- standard error of the measure. r- Pearson correlation coefficient. ICC- Intraclass correlation coefficient. m- meters.

Table 7. Seated Medicine Ball Throw Distance Trial 5 and 6 Statistics

Statistic		Upper Limit	Lower Limit
Δ Means (m)	0.08±0.19	0.15	0.00
r	0.98	0.99	0.96
ICC	0.98	0.99	0.97
Typical Error (CV%)*	3.9	5.4	3.1
SE_m	0.14	0.19	0.11

90% Confidence UL-upper limit, LL-lower limit. *Typical error expressed as a CV% based on Log-transformed data. SEm- standard error of the measure. r- Pearson correlation coefficient. ICC- Intraclass correlation coefficient. m- meters.

4. Discussion

The purpose of this study was to assess the reliability of horizontal distance thrown in a SMBT in healthy, active college students. With a standardized familiarization procedure, it was hypothesized that horizontal distance thrown would be a reliable indicative of upper body explosiveness. In aggregate, the high ICCs, low magnitude of change between trial averages, TE, and SEm, suggest that the hypothesis can be accepted.

Intraclass correlation coefficients for consecutive trial pairs ranged from 0.97-0.99, which, based on ICC reporting standards outlined by Koo and Li [17], indicate "excellent" reliability. In comparison, Gillespie and Keenum [15] found ICC values of 0.95-0.97 in active college males, Lyttle, Wilson, and Ostrowski [16] reported an ICC of 0.93 in regionally competitive athletes, and Harris et al. [1] reported ICCs of 0.969 in older adults, all considered "excellent" reliability. These findings support the notion that using the distance measurement during the SMBT is a reliable measure of for upper body explosiveness.

In addition to the evidence of relative reliability between consecutive trial pairs, there was also evidence to suggest a lack of systematic bias between trials. Both the typical error expressed as a CV (3.2 - 4.7%) and the SEM (0.12 - 0.16m absolute, 3.4 - 4.6% relative to the mean) were very low. These results are comparable to other studies which have reported an SEM of 19.1 cm and 14.8 cm for a 1.5 kg and 3.0 kg MB in older adults [1]. The low SEM and TE observed in the present study, combined with the relative reliability results, indicates that the distance measurement in the SMBT is a highly reliable measure, provided that subjects are adequately familiarized beforehand. If a practitioner were to use this test, assuming that the subject were familiarized prior to the pre-test, a change greater than 0.39m would indicate a high likelihood that a "true" change had occurred (i.e. the change exceeded the smallest detectable difference).

The horizontal distance the thrown medicine ball travels during a SMBT relies on three fundamental factors: velocity during take-off, height at release, and the angle of the release [8]. While height and angle of release affect the distance the thrown medicine ball travels, neither are indicative of the muscle function of the subject performing the test. Thus, some studies have restricted the angle of the throw in some manner [16,29,30] despite early research demonstrating that coaching subjects to an ideal release angle, rather than restricting their release trajectory, results in longer distances and similarly good reliability [15]. Restricted release angle appears to be largely unnecessary given that numerous studies including the present study have found reliable performances despite not controlling release angle in a variety of populations [1,6,15].

The practice effect is a significant concern within experimental designs involving human subjects; it can result in improvements in an activity that involve repetition, purely due to repeated exposures to the test [13,31]. To minimize or eliminate the influence of the practice effect, it is important to have a familiarization protocol set in place. Some studies with the SMBT have documented their familiarization protocol [1,5,6,12,29,32,33,34]; however, many fail to report the protocols used [8,10,16,35], while others don't specify whether or not familiarization was used [15]. Many studies reported using warm up trials [6,8,12,16,29,32-34], which may aid familiarization [31]. Achieving a stable performance requires that subjects perform a sufficient number of practice trials, while ensuring that the effect of fatigue on performance is also minimized [36]. Thus, analysis into the minimum number of trials to reliably complete this maneuver is warranted [4,5]. While many studies have reported their familiarization protocols, no studies have specifically evaluated how much familiarization was necessary before a stable performance was achieved. There is a need to standardize and report familiarization protocols and to report the amount of familiarization necessary for scores to stabilize.

One of the limitations of this study is that the distance of the thrown medicine ball was obtained by careful observation by a researcher who watched for the rearmost point of impact on a nylon tape measure. While this is the most common method for measuring distance, it is dependent on the ability of the observer to accurately identify this point of impact. The within-rater reliability is excellent, according to results from the present study. However, Borrie et al. [37] found some evidence of bias between raters in their study who viewed the same trials ($p = 0.072$, mean difference of 0.03 m). This may result in a small inflation or deflation of observed differences between subjects should the rater be different for each subject, as was the case in our study.

5. Conclusion

Considering the importance of upper body explosiveness to overall health and function, accurate and reliable tests for the assessment of this muscular quality are needed. The results from the present study indicate that for the SMBT, the use of distance thrown is a reliable measure, provided that an adequate familiarization protocol is used. Finally, certain practices used in past studies with the SMBT (e.g. controlling for angle of release), are likely unnecessary to obtain reliable results (see Beckham et al., [5] for further recommendations on best practices for the SMBT).

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